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CONCENTRATION MEASUREMENTS IN EMULSIONS

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by

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ABSTRACT

This paper presents results obtained using a microwave transmission technique for the measurement of the concentration of both phases in simple paraffin-in-water and water-in-paraffin type of emulsions. The results show that by using microwaves, it is possible to detrmine the emulsion type, dispersed phase concentration and inversion point in an emulsion.

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MESURE DE LA CONCENTRATION DES ÉMULSIONS

par

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RÉSUMÉ

Le document fait état des résultats obtenus par la technique de transmission des micro-ondes lorqu'elle a été utilisée pour mesurer la concentration des deux phases dans les émulsions de type simple, telles paraffine dans l'eau, et eau dans la paraffine. Les résultats indiquent que l'utilisation des micro-ondes permet de déterminer le genre, la concentration de la phase dispersée et le point d'inversion d'une émulsion.

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ABSTRACT

This paper presents results obtained using a microwave transmission technique for the measurement of the concentration of both phases in simple paraffin-in-water and water-in-paraffin type of emulsions. The results show that by using microwaves it is possible to determine the emulsion type, dispersed phase concentration and inversion point in an emulsion.

INTRODUCTION

Microwave measurement techniques are excellent tools for investigations of the physical characteristics of dielectric materials with low to medium loss factors. These techniques are used in studies of uniform materials in the solid and liquid phases. Presently, microwave techniques are used for measurements of heterogeneous materials and even complex biological tissues. In many practical applications of these techniques, water is an important and even a dominant component of the investigated material. The selectivity between these techniques depends mainly on the dielectric properties of water.

Water is an important polar material with very distinct dielectric characteristics which strongly depend on frequency and temperature [1]. First, it has a very high relative dielectric constant of about 80, which depends strongly on temperature and remains unchanged from very low frequencies up to about 100 MHz. Secondly, the conductivity of water depends on its impurities and increases from small values for a distilled water to many orders of magnitude higher for saline water. Up to a few MHz, the dielectric characteristics of water are dominated by its conductivity. The relative loss factor of water starts a sharp increase at about 1 GHz. Since its relative dielectric constant starts a strong decrease above 6 GHz, the relative loss factor will eventually become equal to the dielectric constant of water in the range between 15 and 30 GHz depending on temperature. These distinct characteristics of water solely depend on the EM interactions of water molecules and are not affected by interfacial polarization charges of its physical contaminants.

Due to the unique microwave characteristics of water, microwave measurement techniques can be used to determine the water concentration in both heterogeneous industrial media and living matter. Unlike water molecules, the other components of heterogeneous media e.g. oil and coal usually have frequency and temperature independent dielectric characteristics.

This paper presents a new application of microwaves in the oil industry, that is of measuring oil concentration and emulsion type in oil-water emulsions.

COMMON MEASUREMENT TECHNIQUES

In previous studies of the dielectric properties of materials, low frequency capacitance and conductivity measurements were predominantly used [2-4]. These studies have adopted commonly available instrumentation and simple material holders. Those measurements do not require specialized experimental skills. Conductivity measurements of emulsions have the disadvantage of being severely controlled by the salinity of water. Therefore, dielectric measurements at the gigahertz frequencies [5] are preferred in sensing the two phases in oil-in-water emulsions. The cavity approach [6] can not be used for on-line measurements. The transmission technique has the advantage of being easy to use and easy to automate and can be used for continuous monitoring of components of a two-phase system.

MEASUREMENT SET-UP

Figure 1 illustrates the set-up developed for dispersed phase concentration measurements. It consists mainly of an X-band microwave generator, a matching network, two power meters, an A/D converter and an HP data acquisition system. The output is in nanowatts. This output is directly proportional to the transmitted signal and can be calibrated to give the amount of the dispersed phase in certain types of emulsions. The signal also reflects any changes that might occur in the composition, either as changes in concentration or as emulsion inversion. The signal is fed to a microcomputer (HP-85) through an A/D converter for automatic data acquisition.

SAMPLE PREPARATION

Paraffin-in-water emulsions were prepared at room temperature (24°C) using deionized water. A non-ionic emulsifier, Span 80 was added to stabilize the emulsion. Six samples of varying concentrations were prepared, namely, 0, 10, 20, 30, 40, and 50% dispersed phase by weight. To ascertain the stability of the emulsions used, the emulsifier was varied between 1 and 4% depending on the amount of the dispersed phase. The method of preparation was the agent-in-water method where the emulsifier was first dissolved in water and continuously agitated while the paraffin was slowly added and dispersed in the body of the emulsion by the agitator. The emulsion was then mixed in a Waring blender for five minutes at the top speed.

RESULTS AND DISCUSSIONS

Figure 2 gives the results obtained for paraffin-in-water and water-in-paraffin type emulsions measured at 8 GHz. These graphs show that the relationship between detector response and concentration of paraffin/water in emulsion follows two different straight lines with an opposite trends, when plotted on a semi-log paper. At a dispersed phase of 10%, for example,

detector response for water-in-paraffin is about 88 times that for paraffin-in-water which indicates that it is possible by using microwaves to differentiate between emulsion types. It is thus clearly possible using this technique to determine emulsion concentration.

The technique can also be used to detect the inversion point in an emulsion. Results obtained for paraffin-in-water type emulsions showed that the detector response was at least three times higher when the emulsion is inverted from paraffin-in-water to water-in-paraffin (at 50%).

Fig. 2 constitutes the calibration curves for a given sample holder, emulsion type and temperature. If this technique is used to determine the concentration of an emulsion in a pipeline, then at a given frequency and for a certain pipe size, the calibration curves in the form of detector response as a function of dispersed phase concentration can be fitted by a mathematical formula, the coefficients of which can be stored in a microcomputer for automatic evaluation of the dispersed phase concentration. Since the detector response is also a function of the temperature of the emulsion, a simple correction is required.

CONCLUSIONS

A non-radiation type technique has been developed and tested in the laboratory for on-line measurement of the concentration of dispersed phase (paraffin/water) in emulsions. Test results indicate that the technique may also be suitable for the study of emulsion stability and inversion point studies.

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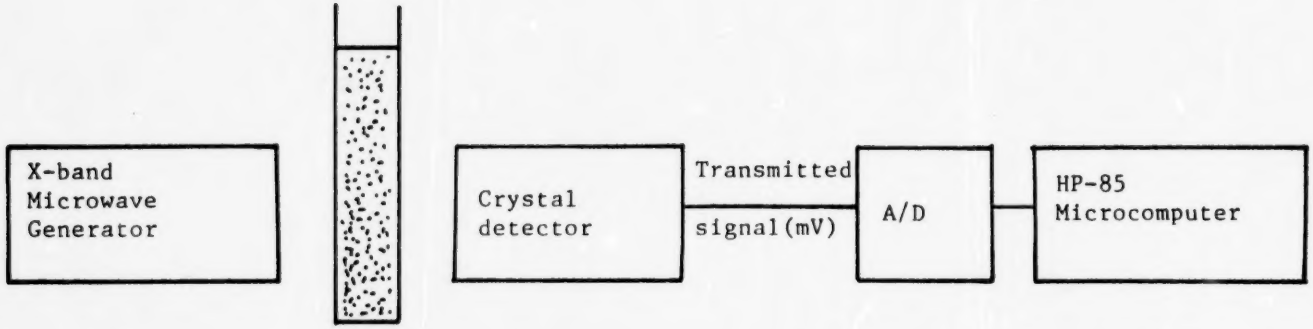

Fig.1 Set-up for dispersed phase measurements in emulsions.

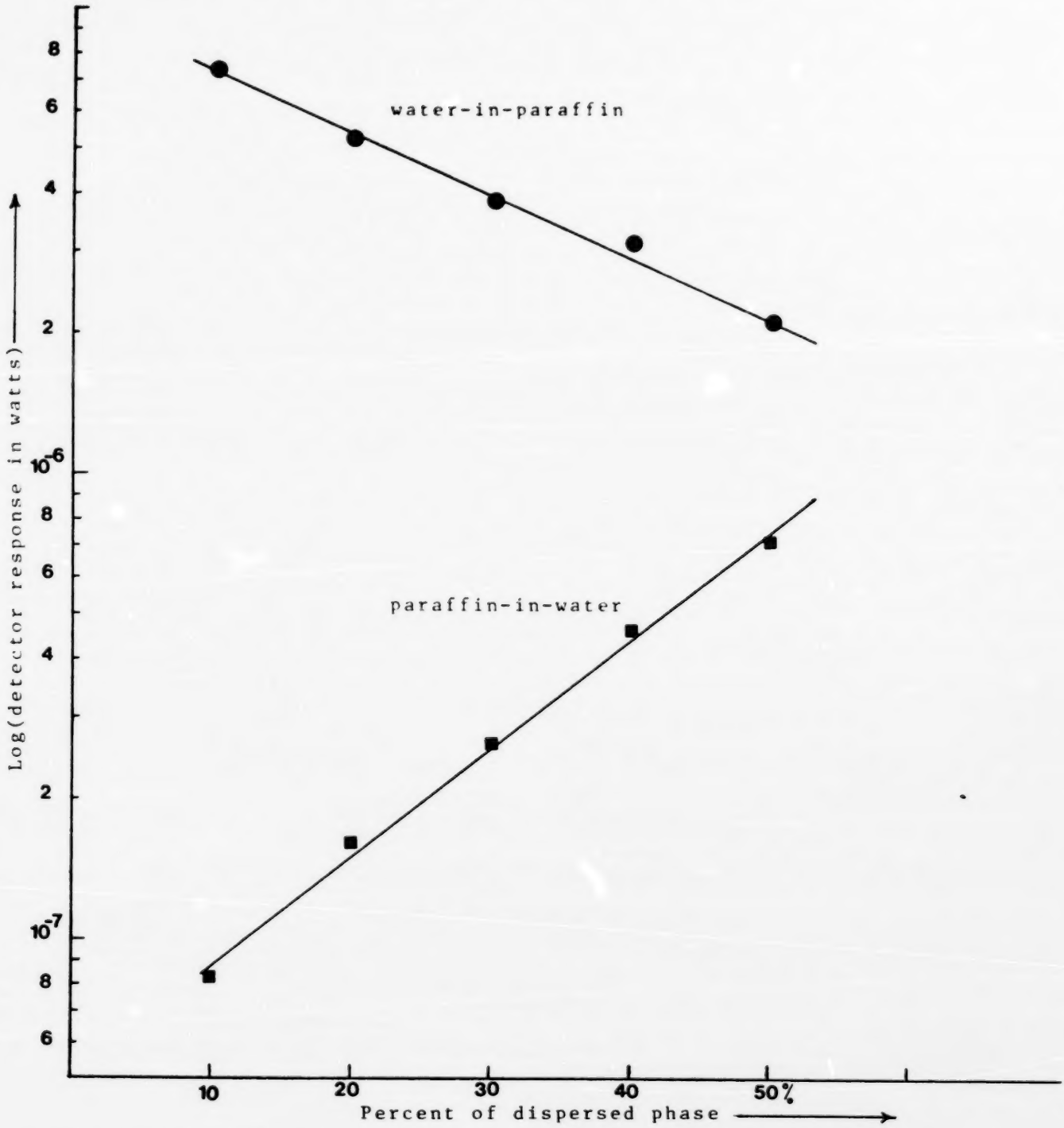

Fig.2 Log of detector response as a function of dispersed phase concentration for two emulsion systems:
1. water-in-paraffin
2. paraffinn-in-water.